Educational Module

Title:

The Answer, My Friend, is…

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Grade Level / Subject:

11^{th} - 12^{th} grade / Physics

Curriculum Standard (from *Benchmarks for Science Literacy* by Project 2061):

- Transformations of energy usually produce some energy in the form of heat, which spreads around by radiation or conduction into cooler places. Although just as much energy remains, its being spread out more evenly means less can be done with it. (4E 9-12 #3)
- Computer modeling explores the logical consequences of a set of instructions and a set of data. The instructions and data input of a computer model try to represent the real world so the computer can show what would actually happen. In this way, computers assist people in making decisions by simulating the consequences of different decisions. (8E 9-12 #1)
- In some cases, the more of something there is, the more rapidly it may change (as the number of births is proportional to the size of the population). In other cases, the rate of change of something depends on how much there is of something else (as the rate of change of speed is proportional to the amount of force acting). (9B 9-12 #1)

Overview:

In this lesson students will explore and learn about cutting-edge renewable energy systems, wind power and fuel cells through an experimental approach. Students will use a wind turbine to derive some quantitative wind power relationships, and will use fuel cells to learn about electrolysis and the up-and-coming use of hydrogen power in energy systems (especially cars). They will then explore and use an on-line computer model to determine the cost of energy of a particular renewable energy system.

Purpose:

The purpose of this lesson is to help students begin to understand the real-world, practical side of the Law of Conservation of Energy: radiant energy from the sun creates irregular heating on earth, which produces wind, which man can convert into electricity using wind-turbines, and which, through electrolysis, can be stored in the form of hydrogen, which can be recombined with oxygen in a fuel cell to form water and electrical energy. Furthermore, they will begin to understand how involved scientific models are, and how much man depends on economic factors to make decisions.

Learning Objectives: After completing this lesson, students will be able to:

- Calculate the power produced by a wind turbine of certain blade diameter and at a certain wind speed.
- Describe the relationship between blade diameter and power for a wind turbine.
- Describe the relationship between wind speed and power for a wind turbine.
- Describe and write the electrochemical equation for the electrolysis of water.
- Calculate the volume of hydrogen produced by electrolysis at different voltages.
- Describe the relationship between voltage and volume of hydrogen produced.
- Create an electrical load profile for a typical home.
- Use a computer model to compare the cost-of-energy of a wind turbine and a fuel cell.

Key Terms:

diurnal variation differential heating wind turbine kilowatt
kilowatt-hour

Resources & Materials:

wind tunnel, variable speed digital wind speed meter power generator station
propellers, variable diameter 6V power supply electrolysis probes
distilled water 400-mL beaker test tubes
10, 100-mL graduated cylinders fuel cell kit
copy of home electricity bill (typical summer month and winter month)
access to internet

Prerequisite Knowledge Students should already know or be familiar with the following:

Basic meteorology (how wind forms).
Basic electric circuitry (series vs. parallel, open vs. closed).
Interrelationships between voltage, current, resistance, and power.
Use of the internet.

Preparatory activities

1. Opener: Think/Pair/Share – What causes the wind?
(Differential heating due to diurnal variation, plus tilt of earth axis.)

2. Journal entry: Have students write about what they know about *wind power* in their journals for a few minutes.

- Historically, when was wind power first used?
- What was it used for?
- What is it used for today?

Discuss ideas and perceptions.

Main Activities (2 days, 85-minute blocks, student-centered stations):

Station 1: Wind Turbine Power

Students obtain propellers of different diameters (3", 4", and 6"); measure and record diameters in mm.
Calculate area swept for each diameter (in^2 and mm^2).
Place small propeller on generator station, and mount in wind tunnel.
Measure and record power generated at wind-speeds of 5, 10, 15, 20 mph.
Convert wind speeds to m/s.
Repeat for all propellers.
Prepare a single graph showing power curves for each propeller.
Derive power curve equation.

Station 2: Electrolysis

Students assemble electrolysis apparatus.
Start electrolysis for 10 minutes at particular voltage.
Measure volumes of gases collected.
Calculate power used.
Repeat at second voltage.
Repeat at third voltage.
Plot volume of gases produced vs. power.
Answer questions.

Station 3: Fuel cells

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